

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/309644575>

REVIEW OF ERGONOMIC SOLUTIONS TO PROTECT FROM INJURIES OF LOWER BACK IN CASE OF FORKLIFTS DRIVERS

Conference Paper · June 2015

CITATION

1

READS

225

3 authors, including:



Brigita Gajšek

University of Maribor

22 PUBLICATIONS 31 CITATIONS

[SEE PROFILE](#)



Goran Dukic

University of Zagreb

20 PUBLICATIONS 96 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Organisations/Organisation/Management [View project](#)



Intra-logistics [View project](#)

REVIEW OF ERGONOMIC SOLUTIONS TO PROTECT FROM INJURIES OF LOWER BACK IN CASE OF FORKLIFTS DRIVERS

Brigita GAJŠEK¹, Goran DUKIĆ², Tihomir OPETUK²

¹University of Maribor, Faculty of Logistics
Mariborska 7, Celje, Slovenia

²University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture,
Ivana Lučića 5, Zagreb, Croatia

Abstract

Sustainability spread during the past few decades is affecting many logistics activities, among them also material handling activities within production and warehousing facilities. Apart from the pure environmental concerns, one should also pay attention to the economic and social part of sustainability. Ergonomic design of forklifts affects both productivity and operator's health and well-being. In this paper we first present an overview of scientific research papers about ergonomics of forklifts, identifying lower back pain injuries as prevalent injury due to the non-ergonomic postures of forklift drivers. In the second part we illustrate some solutions of manufacturers addressing this problem. For the purpose of identifying opportunities of future research we developed schematic model of causes for most present injuries of forklift drivers.

Keywords: ergonomics, forklift, musculoskeletal disorders, low back pain

1. INTRODUCTION

It is showed in [1] that warehouse truck drivers are extensively exposed to work-related illnesses and accidents. Each illness and accident is inseparably connected with involuntary human pain from the point of employee and costs from the point of employer. Results from the study in [2] indicated that ergonomic features in trucks increase productivity. Ergonomics has two basic objectives and indicators to assess the quality of solutions: a positive effect on the health of employees and an economic effect. Features mentioned in [1] addressed with ergonomics should create safer and healthier work conditions in addition to increased productivity, therefore making ergonomic characteristics of forklifts an important area of research. The findings in this area can significantly contribute to both, to productivity and to safe and healthy work conditions. Therefore, success in terms of ergonomics can be a solution that brings positive effect on the health of employees and a simultaneous economic benefit.

Low back pain (LBP) is among the most common and costly health problems [3, 4]. But we should also recall that not only occupational risk factors play role in the development, the duration, and the recurrence of lower back pain. There are presented also non-occupational and individual risk factors for occurrence of low back pain and other rarely developed injuries because of work with forklifts. In this article we will focus only on the occupational risk factors. We will classify them based on review of recent scientific articles.

Ergonomics in connection with forklifts is also interested for research because of its obvious connection with sustainability. The significance of sustainability has developed and spread during the past few decades, affecting in a quite substantial way many logistics activities. Although some might think of sustainable logistics purely as a concept for environmental protection, there are definitely two other pillars of sustainability that should be considered – economic and social. Ergonomics focuses on increasing the efficiency of human work, with two basic objectives and indicators to assess: a positive effect on the health of employees and an economic effect. There are many papers dealing with ergonomics and sustainability. From one recently published [5] “ergonomics has an important and potentially crucial role to play in all sustainability efforts. Technology offers a promising route to a sustainable future, and the way in which humans and technology integrate and coordinate their actions (a question central to ergonomics) is fundamental to the success of this development.” Although authors in [5] concluded that sustainability is a concept that (also) creates problems whose solutions currently fall outside the parameters of normal science

in ergonomics, and that should take into considerations complexity, emergence and ethics in order to achieve “global” sustainability, we agree that sentence “ergonomics has a meaningful part to play in debates about good society and how we should live” is certainly true for “local” sustainability goals within facilities.

In article’s theoretical part we researched main findings from completed scientific work on ergonomics and material handling and linked them to sustainability as written above. In article’s practical part, in order to detect ergonomics solution to protect forklift drivers from injuries and employers from lowering the productivity and unneeded costs, we set following research questions:

- Which injuries affect forklift drivers due to work on forklifts?
- What causes these injuries?
- What solutions are proposed in the scientific literature?
- Is there any special about chronology of research in this area?

Answers were provided by scientific articles review on the topic of ergonomics and forklifts. We classified occupational risk factors based on review of recent scientific articles. According to answers we approached to the review of solutions in practice. As a conclusion, we prepared a graphical model that schematically illustrates the causes for most present injuries.

2. ERGONOMICS IN MATERIAL HANDLING

The aims of ergonomics include creating safe and healthy work conditions, supporting comfort and psychosocial well-being and creating good system performance in terms of both productivity and quality [2, 6]. The area of ergonomics develops all the time and with new technologies and products, so the aims of ergonomics are changing. New criteria are, for example, pleasure and customer joy [2, 7].

Ergonomics as an interdisciplinary scientific discipline based on the principles of human work, which explores the options of adapting work to man and man to work with particular regard to man’s psycho-physiological potential. Although we could trace back the foundations of the science of ergonomics in Ancient Greece, first ergonomic related approaches to industrial tasks are related to work of F.W. Taylor in his „scientific management“. After Second World War, many ergonomic associations appeared. The International Ergonomics Association (IEA) defines ergonomics (or human factors) as “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance”.

Logistics, defined by Council of Supply Chain Management Professionals (CSCMP), is “the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption for the purposes of satisfying customer requirements“. In industrial, trade and service companies many various logistic activities are carried out by human workers who perform a wide variety of movement and storage task. The importance of ergonomics in the field of logistics is placed mainly in the compliance of technical solutions and product features, and their adaptation to human capabilities and needs. The benefits are evident - from such an ordinary aspect as enjoying the work in a pleasant environment with easy-to-operate machines, up to the documentable increase of job performance or reduction of errors/defects [8].

Within facilities, production or assembly plants and warehouses or distribution centres, movement and storage of physical loads fall within their internal logistics' material handling activities. There are plenty sources, documents and reports about importance of ergonomics for material handling. However, most deal with manual material handling. This is of course logical. Musculoskeletal disorders (MSDs) can appear because of exposure to one or more risk factors in manual handling of physical loads. There is a risk because:

- awkward postures (e.g., bending, twisting),
- repetitive motions (e.g., frequent reaching, lifting, carrying),
- forceful exertions (e.g., carrying or lifting heavy loads),
- pressure points (e.g., grasping or contacting loads, leaning against parts or surfaces that are hard or have sharp edges), and
- static postures (e.g., maintaining fixed positions for a long time).

Repeated or continual exposure to one or more of these factors may lead to fatigue, discomfort and injuries. Scientific evidence shows that effective ergonomic interventions can lower the physical load of manual

material handling work tasks and causally lead to lower incidence and severity of the musculoskeletal injuries. Their potential for reducing injury related costs alone make ergonomic interventions a useful tool for improving a company's productivity, product quality, and overall business competitiveness [9]. Lowering of MSDs in material handling can be achieved by eliminating the need for manual material handling or reducing it, altering the process, implementing various ergonomic-assisting devices, or mechanizing/automating the process. Mechanization of material handling activities of transport, stacking, storing is usually carried out by using various industrial trucks, most commonly forklifts.

Forklifts are one of the most widespread internal transport vehicles due to the flexibility of transportation of materials and the ability of carrying different weight loads. In a typical storage environment, capacity range is from 1 to 5 tons. In extreme cases, where we use special trucks (for containers), load capacity can be up to 50 tons. Popularity and the need for forklifts in production and warehouse environments present figures from 2013, when 20 largest manufacturers of forklifts worldwide generated revenue of 31.45 billion USD with sales of 1,009,777 forklift units [10]. Most forklifts are used in transport and logistics industry, trading with food and beverages industry, and in other trading/retailing industries [11]. The same source further states that 38% of forklifts are used in manufacturing industries. Data is based on the national statistics per industry of France, Germany and Great Britain and is weighted by size of national market.

However, forklifts are operated by human operators. In spite of machine-supported transshipments of material, potential awkward postures, repetitive motions and static postures are still present during the work. Forklift operators spend a vast majority of their time sitting and twisting their upper parts of bodies, resulting in a number of physical strains. Improvements of forklift's ergonomics are critical for ensuring high operators productivity. Various advances in technology had improved operator's comfort, but this task is still challenging for forklift manufacturers and academic researchers, especially with the objective to protect the operator's lower back.

3. OVERVIEW OF SCIENTIFIC PUBLICATIONS ON HEALTH PROBLEMS AT FORKLIFT DRIVERS

A literature review of international scientific publications on ergonomics and forklift from several databases was conducted. We reviewed eleven articles written between years 2001 and 2013 (Table 1). We wanted to answer on following research questions:

- Which injuries affect forklift drivers due to work on forklifts?
- What causes these injuries?
- What solutions are proposed in the scientific literature?
- Is there any special about chronology of research in this area?

Table 1 – A literature review on ergonomics and forklift to research injuries and causes for them

Author	Type of injury	Cause for injury	Experiment	Conclusions
Shinozaki, Yano, Murata (2001) [12]	Lower back pain	Not wearing protective equipment, passive posture, non-ergonomically designed seats, inappropriate tires.	The self-reported prevalence of LBP was surveyed 3 times before and after the 2 forms of interventions, between more than 310 workers.	Providing lumbar support, arctic jacket and physical exercise reduced the prevalence from the initial survey significantly. The improvement of forklift seats and tires reduced the prevalence from the initial survey near significantly.
Solman (2002) [2]	Musculoskeletal loads and discomfort	Certain type of task, the design of the steering arm, the design of loading ramps, poorly conceptualized human-machine systems	29 pallet truck drivers have been involved at 2 Swedish distribution companies.	Time pressure, high workload and peaks in workload cause stress in a form of mental impact. Computerized equipment in the trucks can increase the mental impact. Platform, steering arm and truck size are main reasons for human-machine interaction deficiencies. The drivers' own view is that the driving over the loading ramps causes the discomfort in the low back. The lower back, neck and shoulders were the most affected body parts for physical impact.
Hoy, Mubarak,	Lower back pain (LBP)	Whole body vibration (WBV),	A cross-sectional study, forklift vibrations at the	LBP was more prevalent amongst forklift drivers and driving postures in

Nelson, Sweerts de Landas, Magnusson, Okunribido, Pope (2005) [13]		postural stress from static work postures, particularly bending and twisting, the neck extended backward	seat (exposure) were measured	which the trunk is considerably twisted or bent forward. Forklift drivers showed to be exposed to acceptable levels of vibration in the x- and y-directions but not in the z-direction. WBV acts associatively with other factors to precipitate LBP.
Waters, Genaidy, Deddens, Viruet (2005) [14]	Musculoskeletal disorders (MSDs), such as lower back pain and neck problems	Static sedentary position; short and long-term awkward trunk postures; short and long-term awkward neck postures during reverse operation; whole-body vibration while driving	A comprehensive search of databases	Awkward postures, whole-body vibration, and their synergistic effects should be further researched.
Hulshof, Verbeek, Braam, Bovenzi, Dijk (2006) [15]	Lower back pain (LBP), spinal disorders	Whole body vibration (WBV)	An experimental pretest/post-test control group study design. In total, 260 forklift drivers were involved.	In cases where control measures (levelling of surface, reduction of speed) had been taken, there was a significant reduction in WBV exposure.
Jouberta, London (2007) [16]	Lower back pain (LBP)	Back belt usage, whole-body vibration (WBV)	Cross-sectional analytical study design amongst 158 drivers using back belts and 39 controls	Back belt use for WBV exposed professional drivers should not be considered as a valid control measure to reduce the prevalence and intensity of LBP.
Viruet, Genaidy, Shell, Salem, Karwowski (2008) [17]	Lower Back Pain	Whole body vibration (WBV), awkward postures and static postures	(1) formulation of a clear research question; (2) search of the literature for the best evidence with which to answer the question; (3) critically appraise the evidence; (4) implement useful findings	Operators exposed to driving forklifts are greater than twice the risk of those not exposed to driving forklifts to experience lower back pain. Awkward postures and static postures are affected by cab design, seat, time spent seated, and the task performed. Some aspects of the work environment that influence vibration are seat, speed, track, and tires.
Kim, Im, Chung (2008) [18]	Discomfort	An unacceptably high level of acoustic noise in an induction motor	A three-phase induction motor for powering a forklift is adopted as a test motor.	Two design guidelines are suggested to realize an induction motor with a low noise level.
Choi a, Park, Kim, Hallbeck, Jung (2009) [19]	Discomfort, striking pedestrians or other vehicles, falling-off a ramp or loading dock, and turning over by hitting obstacles	Insufficient visibility	Study applied the light bulbs shadow test, a manikin vision assessment test, and an individual test to a forklift truck.	The design factors of load backrest extension, lift chain, hose, dashboard, and steering wheel should be the first factors considered to improve visibility, especially when a forklift truck mainly performs a forward traveling task in an open area.
Blood, Ploger, Johnson (2010) [20]	Occupational low back pain (LBP)	Exposure to whole body vibration (WBV)	12 forklift operators drove the same forklift with a mechanical suspension and an air suspension seat	Different seat suspensions can differently influence WBV transmission and some components of vibration transmission are dependent on the weight of the driver.
Rislund, Hemphälä, Hansson, Balogh (2013) [21]	Musculoskeletal disorders (neck, shoulder, arm, lower back)	Small steering wheel	12 male subjects conducted identical test cycles with 3 types of steering: normal, tilted and miniature.	The effects of the miniature steering wheel indicate an increased risk for over exertion resulting in disorders of the wrist and forearm for the left side.

In the analysed papers of “ergonomics + forklifts” publications 2001–2013, 67% mentioned lower back pain, 25% discomfort, 17% neck problem and 8% spinal disorders, musculoskeletal disorders, shoulder and arm.

Lower back pain is the most frequently mentioned damage that affects forklift drivers due to work on forklifts. The lower back, neck and shoulders were scientifically proven the most affected body parts for physical impact. LBP was more prevalent amongst forklift drivers and driving postures in which the upper body is considerably twisted or bent forward. Workers exposed to driving forklifts have more than twice greater risk to experience lower back pain of those workers not exposed to driving forklifts.

Causes for mentioned injuries can be divided in several causal areas:

- personal protective equipment (not wearing lumbar support, arctic jacket),
- medical prevention (physical exercise, low body weight of the driver),
- forklift design (inappropriate seat, tires, shape of the frame, seat suspension, steering wheel/arm),
- workspace (levelling of surface, loading ramp, track),
- human-machine systems (computerized equipment), and
- work characteristics (speed, static work postures, whole body vibrations, time spend sited, work load, type of task performed, level of noise).

In the same set of “ergonomics + forklifts” publications 2001–2013, 67% mentioned work characteristics, 33% forklift design and 8% human-machine systems, personal protective equipment, prevention, workspace as causes for all kind of injuries related to work with forklift. Bad work characteristics are caused because of forklift design, workspace and human-machine systems. Indirectly it can be concluded that forklift design has the greatest influence on injuries because of driving the forklift, although we can not specify what part of work characteristics can be further added to forklift design.

Regarding on solutions, authors verified quite a few assumptions. They proved that providing lumbar support, arctic jacket and physical exercise reduce the possibility of injury significantly. The improvement of forklift seats and tires reduced the possibility of injury near significantly. Greater comfort and less pain in lower back can be achieved by cleverly designed loading ramps. In cases where control measures (levelling of surface, reduction of speed) had been taken, there was a significant reduction in whole body vibration (WBV) exposure. Back belt use for WBV exposed professional drivers should not be considered as a valid control measure to reduce the prevalence and intensity of LBP. Awkward postures and static postures are affected by cab design, seat, time spent seated, and the task performed. Some aspects of the work environment that influence vibration are seat, speed, track, and tires. Different seat suspensions can differently influence WBV transmission and some components of vibration transmission are dependent on the weight of the driver. The effects of the miniature steering wheel indicate an increased risk for over exertion resulting in disorders of the wrist and forearm for the left side.

We can conclude that authors of scientific papers deal not only with improvements of forklift design but they are interested in different kind of solutions for the elimination of a full range of reasons for the injuries due to the use of forklifts. Awkward postures, whole-body vibration, and their synergistic effects should be further researched because whole-body vibration acts associatively with other factors to precipitate lower body pain.

4. OVERVIEW OF ERGONOMIC SOLUTIONS ON VARIOUS FORKLIFTS

We prepared a short illustrative overview of the some solutions offered by the manufacturers of forklifts due to over assumption that forklift design has the greatest influence on injuries because of driving the forklift.

Various forklift manufacturers address differently to ergonomic issues for lowering risks of neck and torso injuries during operations in storage aisles. One example of unique approach is the Raymond Corporation’s Universal Stance design, illustrated in Figure 1, which allows lift truck’s operators to stand facing forward in the direction of the work being done. Described is the optimum ergonomic configuration for pallet handling.

The human body standing is in an ergonomically neutral posture with hands and arms down at the sides, while head and torso are facing forward. Analysis of work in today’s warehouses with many, usually narrow aisles and relatively high racks revealed that usual side stance designs of forklifts have reduced visibility while traveling up and down the aisle and when exiting the aisle, as illustrated in Figure 2, forcing operators to turn their torsos in not ergonomic and potentially risk positions.



Figure 1 – Universal stance in forks-first travel and tractor-first travel [22]

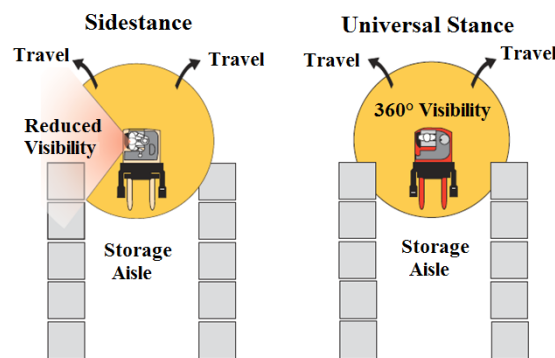


Figure 2 – Sidestance and universal stance forklift's visibility [22]

During the pallet storage or retrieval operations in aisles, operators have to look up at high angles to manipulate loads. With the sidestance design neck is already rotated, and looking up puts the neck at risk for muscle and spine damage. Figure 3 illustrates how biomechanics of the neck limit the tilt angle of the head when neck is also rotated.

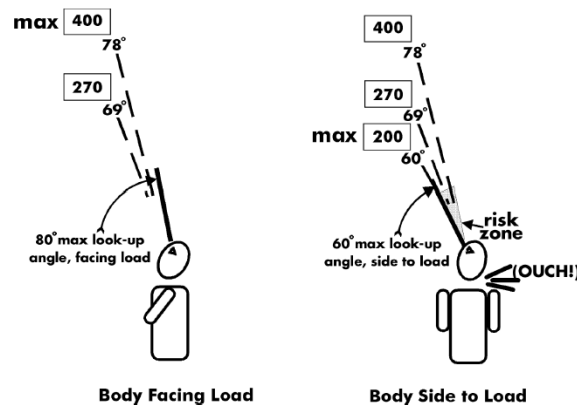


Figure 3 – Comparison of maximum no-strain look up angles [23]

According to the [23], turned sideways to the load, the maximum look-up angle without strain is 60°, which equates to about 5 meters in height. Standing facing the load, the maximum look-up angle without strain is 80°, which equates to just over 10 meters in height. This problem is even greater with design of some side stance forklifts that place the head behind the mast, forcing the operator to lean forward, or, more seriously, lean backward out of the protective compartment of the truck to see loads high up [22]. Eliminating need for twisting torso during driving and looking up with twisted neck while manipulating loads at heights are reducing risk of repetitive stress injury.

Improved ergonomics confirmed in [24] for Linde's forklifts with swivel seats is another example of how manufacturers address ergonomic problems for forklift operators with required twist of torso and neck, illustrated in Figure 4.

In its “comparative, ergonomic investigation of the forklift truck” the school of ergonomics at the Technical University of Munich analyzed and compared various working seats. The swivelling seat in the Linde truck reduces the twisting of the torso and body by 13.9°, while the visibility is improved by 11.6° in a 17° swivelled seat with Linde twin accelerator pedals [25].



Figure 4 – Forklift design with the rotating seat [25]

Another solution from Linde provides even more comfort and safety while driving backward, illustrated in Figure 5. The operator can rotate the entire driver's seat through 90°. The driver sits at an angle to the direction of travel and has an unrestricted view of the driving route.



Figure 5 – 90° rotating seat [26]

With the same idea of drivers' repetitive non ergonomic movement reduction while driving backward is the solution of rotating cabin. Linde offered this solution for heavy trucks [27] and Jungheinrich for smaller electric warehouse forklifts [28] (Figure 6).



Figure 6 – Forklift with rotating cabin [29]

Rotating cabin, for example in case of Jungheinrich's solution, can be rotated for 30° to the left as well as for 180° to the right. This solution can be considered as a combination of swivel seat for shorter moves backwards, rotation of cabin through up to 90° for an adequate and comfortable view to the rear for short and medium-long distances - comparable with a reach truck, or rotate the cabin for up to 180° for travelling over longer distances.

5. CONCLUSIONS

Warehouse truck drivers are extensively exposed to work-related illnesses and accidents. Considering that 20 largest manufacturers of forklifts worldwide sale more than 1,000,000 forklift units per year there is a huge need for mitigation of this situation. Efforts with positive effects would increase forklifts drivers' satisfaction, reduce costs for companies, speeding up the material handling and have positive impact on sustainability.

Figure 7 presents from scientific literature review derived causes for lower back pain and drivers' discomfort. Lower back pain was exposed because it is characterized as most frequently mentioned damage that affects forklift drivers due to work on forklifts. We distributed causes in five causal areas, namely forklift, forklift driver, human-machine system, workspace and process. Bad work characteristics are mostly caused because of inadequate forklift designs, reckless workspace and because of missing or poor human-machine systems. Indirectly it can be concluded that forklift design has the greatest influence on injuries because of driving the forklift, although we can not specify which bad work characteristics are influenced by forklift design.

The key year in research of forklift drivers' injuries was 2005. Then it was discovered that lower back pain is most prevalent amongst forklift drivers and driving postures in which the trunk is considerably twisted or bent forward. Whole body vibration acts associatively with other factors to precipitate lower back pain. In practice, we identified four conceptually different approaches to reduce the need for partial rotation of the upper body, namely no seat approach, sidestance, rotating seat for certain angle and rotating cabin. The impact of these technical solutions (some of them illustrated in Chapter 5) on productivity has not been surveyed, but it is provable that reduce damage to the drivers of forklifts. In the article we discovered that there are also other potential areas to find solutions that would help to reduce the occurrence of lower back pain. These are human-machine system, forklift driver, workspace, and processes. In the future, we expect more research to investigate the possibility of synergistic effects of partial solutions across multiple causal areas together.

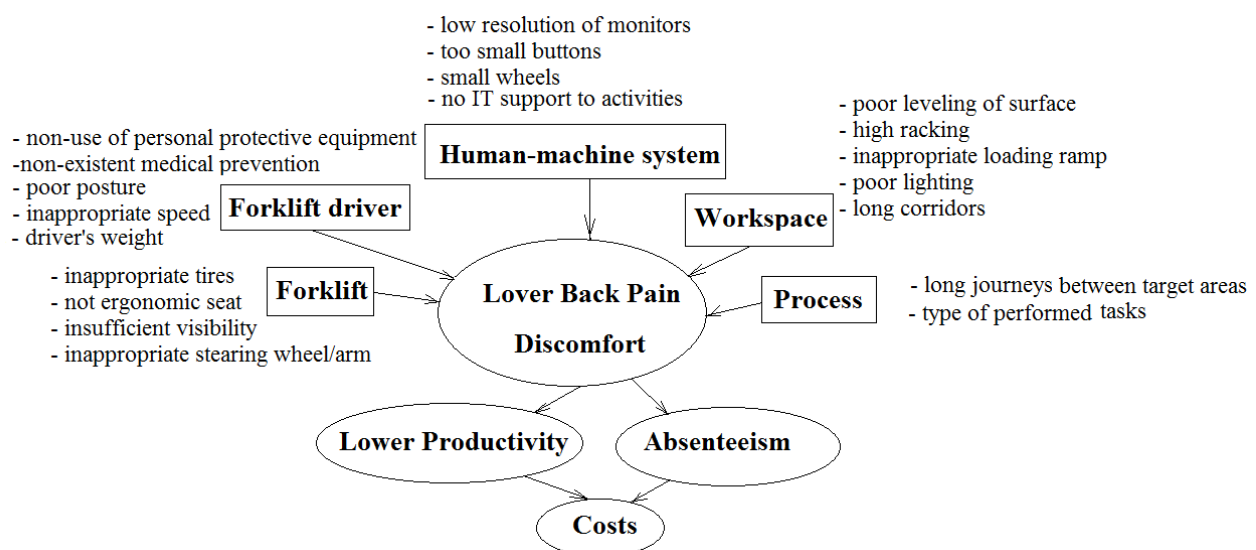


Figure 7 – Causes for LBP and its consequences

In area of ergonomics of forklifts there is still a potential for future research. Many ergonomic studies have been performed involving warehouse forklifts or other work vehicles, but few of these had a holistic ergonomics perspective which means that productivity and quality, in addition to safety, health and well-being, are studied together. We also believe that for every novelty would be highly recommended to examine its impact on the health of the driver and on the productivity.

6. REFERENCES

- [1] Nolino, K.: *Productivity in a driver-forklift system*, Master Thesis, University of Technology, 1996.
- [2] Solman, K. N.: *Analysis of interaction quality in human-machine systems: applications for forklifts*, Applied Ergonomics, 33(2002)2, 155-166.

- [3] Garg, A., Moore, J. S.: *Epidemiology of low-back pain in industry*, Occupational Medicine.
- [4] van Tulder, M. W., Koes, B. W., Bouter, L. M. A.: *Cost of illness, study of back pain in The Netherlands*, Pain, 62(1995), 233-240.
- [5] Dekker, S. W., Hancock, P. A., Wilkin, P.: *Ergonomics and sustainability: towards an embrace of complexity and emergence*, Ergonomics 56(2013)3, 357-364.
- [6] Ruth, W., Odenrick, P.: *Begreppet "ergonomi" - vad står det för?*, In Nordisk Ergonomi, 3(1994).
- [7] Jordan, P.W.: *Designing Pleasurable Products: An Introduction to the New Human Factors*, Taylor & Francis, London, 2000.
- [8] Beno, R.: *Ergonomics in Business Logistics*, Technische Universität Ilmenau / University Library, Universitätsverlag Ilmenau, 2013.
- [9] National Institute for Occupational Safety and Health (NIOSH): *Ergonomic Guidelines for Manual Material Handling*, California Department of Industrial Relations, Cincinnati, 2007.
- [10] Bond, J.: *Top 20 lift truck suppliers, 2014*, www.mmh.com/article/top_20_lift_truck_suppliers_2014, 13-04-2015.
- [11] Boekhoff, H.: *Facts: Industrial Truck Market*, www.fem-eur.com/data/File/N284-FEM-IT-NC_Fact_Sheet_Europe_2014.pdf, 15-04-2015.
- [12] Shinozaki, T., Yano, E., Murata, K.: *Intervention for prevention of low back pain in Japanese forklift workers*, American Journal of Industrial Medicine, 40(2001)2, 141-144.
- [13] Hoy, J., Mubarak, N., Nelson, S., Sweerts de Landas, M., Magnusson, M., Okunribido, O., Pope, M.: *Whole body vibration and posture as risk factors for low back pain among forklift truck drivers*, Journal of Sound and Vibration, 284(2005), 933-946.
- [14] Waters, T., Genaidy, A., Deddens, J., Barriera-Viruet, H.: *Lower Back Disorders Among Forklift Operators: An Emerging Occupational Health Problem?*, American Journal Of Industrial Medicine, 47(2005), 333-340.
- [15] Hulshof, C. T. J., Verbeek, J. H. A. M., Braam, I. T. J., Bovenzi, M., van Dijk, F. J. H.: *Evaluation of an occupational health intervention programme on whole-body vibration in forklift truck drivers: a controlled trial*, Occupational and Environmental Medicine, 63(2006)7, 461-468.
- [16] Joubert, D. M., London, L.: *A cross-sectional study of back belt use and low back pain amongst forklift drivers*, International Journal of Industrial Ergonomics, 37(2007), 505-513.
- [17] Viruet, H. B., Genaidy, A., Shell, R., Salem, S., Karwowski, W.: *Human Factors and Ergonomics, Manufacturing*, 18 (2008)2, 125-151.
- [18] Kim, W., Im, H., Chung, J.: *Noise reduction of an induction motor for a forklift*, Journal of Mechanical Engineering Science, 223(2009)Part C, 1311-1317.
- [19] Choi, C. B., Park, P., Kim, J. H., Hallbeck, M. S., Jung, M. C.: *Comparison of visibility measurement techniques for forklift truck design factors*, Applied Ergonomics, 40(2009), 280-285.
- [20] Blood, R. P., Ploger, J. D., Johnson, P. W.: *Whole Body Vibration Exposures in Forklift Operators: Comparison of a Mechanical and Air Suspension Seat* Ergonomics 53(2010)11, 1385-1394.
- [21] Rislund, C., Hemphälä, H., Hansson, G., Balogh, I.: *Evaluation of three principles for forklift steering: Effects on physical workload*, International Journal of Industrial Ergonomics, 43(2013), 249-256.
- [22] *Universal Stance Helps Lift Truck Operators Perform Better*, The Raymond Corporation, www.raymondcorp.com/images/pdf/Universal_Stance_helps_operators.pdf, 16-04-2015.
- [23] Noonan, T.: *Ergonomics and Reach Truck Applications*, The Raymond Corporation, 1994.
- [24] Schröder, F., Seitz, T., Hudelmaier, J.: *Swivel Seat Improves Ergonomics*, Linde AG, Institute of Ergonomics at the Technical University of Munich, 2004.
- [25] *Achieve more and safely*, Linde, www.liftec.com/sites/liftec/files/linde_brochure_39X_dr.pdf, 15-04-2015.
- [26] Oder, H.: *Linde MH presents its rotatable driver's seat*, www.linde-mh.com/en/main_page/news/pressreleases/pressreleases_1_1728.jsp, 15-04-2015.
- [27] *Rotating Cabin*, Linde Material Handling, www.lindeheavytruck.com/media/cmp_1401/Datasheet_Rotating_cab.pdf, 15-04-2015.
- [28] *World's first rotating cabin lift truck*, Logistics & Materials Handling, www.logisticsmagazine.com.au/news/world-s-first-rotating-cabin-lift-truck, 15-04-2015.
- [29] *Electric Forklift Truck features 180-degree rotating cabin*, Industry News, news.thomasnet.com/fullstory/electric-forklift-truck-features-180-degree-rotating-cabin-505073, 15-04-2015.